VIIRS Land Surface Reflectance Algorithm for NPOESS

A. Sei[1] and E. Vermote[2]

[1]Northrop Grumman Space Technology
[2]University of Maryland

Introduction

Abstract:
The VIIRS Surface Reflectance algorithm produces an intermediate product (IP) which is a key input to many land products including, surface type, albedo and vegetation index. The algorithm is similar to the MODIS algorithm used to produce the land reflectance MOD09 product. In this presentation we compare the output of the VIIRS and MODIS surface reflectance algorithms for two MODIS granules . We also compare the pixel level aerosol retrieval since this is key input to the atmospheric correction performed by the reflectance algorithm.

Background:
The VIIRS surface reflectance algorithm performs atmospheric corrections of the top of the atmosphere reflectance. These corrections aim at removing the blurring effects of aerosols and trace gases present in the atmosphere to yield an intrinsic surface quantity. The MODIS and VIIRS algorithms produce the Lambertian reflectance at ground level. Adjacency effects and BRDF effects were evaluated and deemed negligible on the scale of the VIIRS/MODIS footprint.

Both the VIIRS and MODIS surface reflectance algorithms are look-up tables (LUT) based algorithms. The LUT store the output of the complex radiative transfer processes modeled by numerical algorithms; in both cases the 6S radiative transfer model is used to produce the LUT. The retrieval of the surface reflectance from the top of the atmosphere reflectance is achieved once the aerosol properties, surface pressure, ozone and water vapor concentration are known. Once these parameters are known, the atmospheric reflectance (contribution to the ToA signal due to the atmosphere alone) can be removed and the part of the signal due to the (Lambertian) surface can be isolated. Once the surface part of the signal is known the surface reflectance is obtained in closed form. The main difference between the MODIS and VIIRS algorithm comes in the retrieval of the aerosol properties, namely the aerosol model and the aerosol optical thickness at 550 nm. The VIIRS aerosol retrieval is based on a mapping between SWIR and blue and red bands (similar to the MOD04 product). The MOD09 product is based on a mapping between blue and red bands.

VIIRS surface reflectance algorithm

The VIIRS surface reflectance algorithm produces atmospherically corrected reflectances in the following moderate resolution bands (750 m @ nadir) M1 (412 nm), M2 (445 nm), M3 (488 nm), M4 (555 nm) , M5 (672 nm), M7 (865 nm), M8 (1240 nm), M10 (1670 nm) and M11 (2250 nm). It also produces atmospherically corrected reflectances in the following imagery resolution bands (375 m @ nadir) I1 (640 nm), I2 (865 nm) and I3 (1610 nm).

The surface reflectance ρ_s is related to the top of the atmosphere reflectance ρ^{TOA}, the atmospheric path reflectance ρ^{atm} and the atmospheric (T^{atm}) and gaseous (T^{gas}) transmittances as follows:

$$\rho^{TOA} = T_{gas}\left(\rho^{atm} + \frac{T_{atm}\rho_S}{1 - S\rho_S}\right) \qquad (1)$$

Once the atmospheric constituents are know, the transmittance and atmospheric path reflectance can be derived (interpolated) from store LUT values and ρ_s can easily been retrieved.

The following plots compare the VIIRS surface reflectance product to the MODIS collection 5 surface reflectance product. These comparisons provide a sound check of the VIIRS algorithm and also points out the impact of differences between the two algorithms. The VIIRS algorithm is essentially identical to the MODIS algorithm in its core module (implementation of equation (1) above), but differs significantly in its main inputs, most importantly cloud mask and aerosol properties retrieval.

In order to minimize differences we chose to compare pixels that were flagged as confidently clear by both algorithm cloud masks. We also compared high quality retrieval for aerosol optical depth and surface reflectance as indicated by the quality flags of each algorithm. Finally in order to put these comparisons in context we plotted as dotted lines on the performance attribute plots (accuracy, precision and uncertainty) the estimated performance of the reflectance MODIS product and the current NPOESS system specification threshold for the aerosol optical depth.

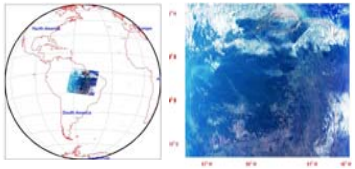
The current estimate of performance for the surface reflectance is 0.005 +0.05*ρ. Regarding the aerosol optical depth over land the NPOESS system specification states an uncertainty of 0.05 + 0.15*τ.
More details regarding the estimate of performance and validation of the MODIS product can be obtained at the following site: http://mod09val.ltdri.org/cgi-bin/mod09_c005_public_allsites_onecollection.cgi.

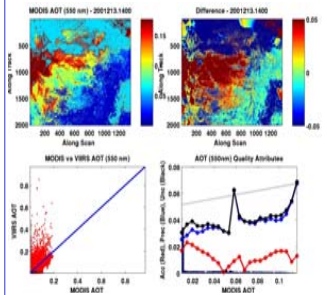
The results show that except for the blue band M3 the difference between VIIRS and MODIS outputs are well within the estimated validated performance of the MOD09 product. The larger error for the blue band is due to the fact that this band is most sensitive to the aerosol model and optical thickness values. As depicted in the aerosol retrieval comparison plot, the aerosol optical depth retrievals are quite different especially for the second granule and therefore the M3 reflectance performance is degraded. Other bands fare much better since they are relatively less impacted by an error in the path reflectance.

For the first granule however where a good agreement between the VIIRS and MODIS aerosol optical depth was observed the performance of the blue band is also very good, essentially within the error bar derived from validation of the MODIS product.

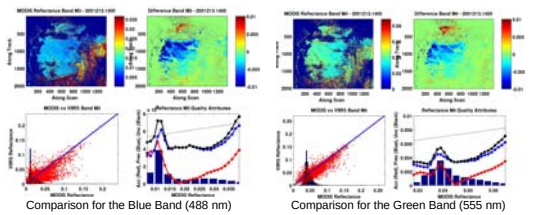
Surface Reflectance Comparison / Testing

Granule 2001213.1400



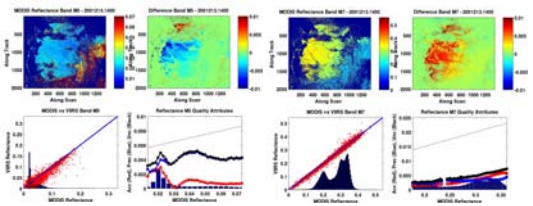


Comparison of Aerosol pixel level retrievals



Comparison for the Blue Band (488 nm)

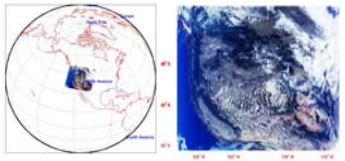
Comparison for the Green Band (555 nm)

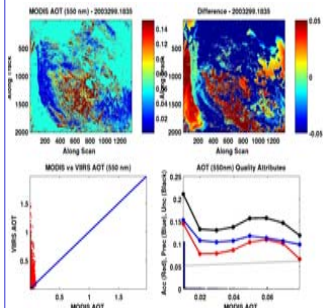


Comparison for the Red Band (672 nm)

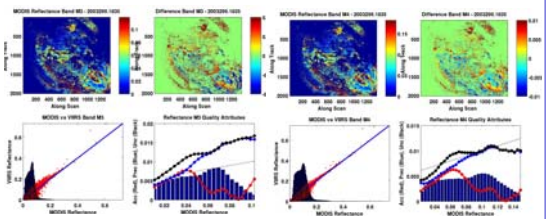
Comparison for the NIR Band (865 nm)

Granule 2003299.1835



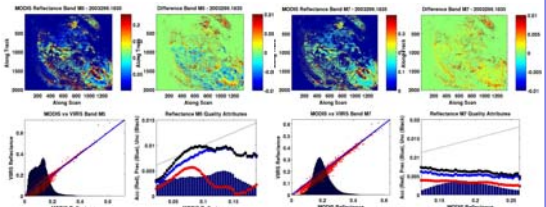


Comparison of Aerosol pixel level retrievals



Comparison for the Blue Band (488 nm)

Comparison for the Green Band (555 nm)



Comparison for the Red Band (672 nm)

Comparison for the NIR Band (865 nm)

Conclusions

The tests and evaluation of the VIIRS surface reflectance algorithm shows excellent performance when compared to the heritage MODIS collection 5 algorithm. When aerosol properties (retrieved by two different algorithm) are in good agreement the VIIRS and MODIS surface reflectances are within the MOD09 validation error bars.